Sewage Effluent and Irrigation

M.J. Melton

There is general agreement that water of good quality is in limited supply. It is one of the reasons that man began to use wastewater directly on farmlands long ago.

There was always the risk to public health from eating uncooked fruits and vegetables grown on lands irrigated by wastewater because of the presence of disease-causing organisms (pathogens) from man's biological wastes. These organisms include helminths (parasitic worms), protozoa, bacteria, and viruses.

In the last century, wastewater has come to include heavy metals and toxic organic substances. With time, man saw that raw sewage would have to be treated before use in irrigation.

In 1988, a book titled TREATMENT AND USE OF SEWAGE EFFLUENT FOR IRRIGATION edited by M.B. Pescod and A. Arar was published by arrangement with the Food and Agriculture Organization (FAO) of the United Nations by Butterworths. This book covers the proceedings of the FAO Regional Seminar on the treatment and use of sewage effluent for irrigation that was held in Nicosia in Cyprus from the 7th to 9th of October in 1985. With the suggestions given in this book, a good management team can establish the necessary guidelines for reusing wastewater for a specific location.

In chapter four, A. Kandiah of the Land and Development Division of the FAO in Rome gives some guidelines which should be considered when reusing wastewater for agricultural purposes. In his paper, " Quality Criteria in Using Sewage Effluent for Crop Production", the main references for these criteria are a World Health Organization (WHO) report on re-use of wastewater published in 1973 and an FAO report on water quality for agriculture published in 1985.

Kandiah's paper takes a look at reusing municipal wastewater which is defined as the spent water of a community consisting of water-carried wastes from residences, commercial buildings, and industrial plants and surface or groundwater that enters the sewerage system (WHO,1973). Whether this municipal wastewater can be re-used for agricultural purposes depends largely on if it is more economical to reclaim wastewater for a certain need or to get water from another source. This problem is seen more in developing countries where typical municipal wastewater is of a stronger concentration because of the scarcity or cost of water so that treatment of wastewater to remove substances harmful to agriculture is more expensive.

When considering the use of reclaimed wastewater for irrigation, it is first important to know its microbial and biochemical properties. With these values, the risk to public health, the danger to the environment, and the considerations for agriculture (mainly salinity of the wastewater) can be evaluated. Although it is true that agriculture can accept a lower quality of water than domestic (drinking and washing purposes) or industrial users, there still must be quality criteria for irrigation water because of the effects on users of agricultural products or on soils, plants and the farm environment.

The guidelines presented by WHO (1973) and FAO (1985) can be combined along with a local site evaluation by a potential user of municipal wastewater. Kandiah suggests combining Tables 4.2, 4.3, and 4.4 as a first step in assessing the quality limitation of the wastewater. Then good management practices can provide other alternatives if water quality is low.

Tables 4.2 and 4.3 help

Table 4.2 Guidelines for interpretation of water quality for irrigation

Potential irrigation problem	*Units*	*Degree of restriction on use*		
		None	*Slight to moderate*	*Severe*
Salinity (affects crop water availability)*				
EC_w	dS/m	<0.7	0.7–3.0	>3.0
or				
TDS	mg/l	<450	450–2000	>2000
Infiltration (affects infiltration rate of water into the soil. Evaluation using EC_w and SAR together)†				
SAR = 0–3 and EC_w =		>0.7	0.7–0.2	<0.2
= 3–6 =		>1.2	1.2–0.3	<0.3
= 6–12 =		>1.9	1.9–0.5	<0.5
= 12–20 =		>2.9	2.9–1.3	<1.3
= 20–40 =		>5.0	5.0–2.9	<2.9
Specific ion toxicity (affects sensitive crops)				
Sodium (Na)†				
surface irrigation	SAR	<3	3–9	>9
sprinkler irrigation	me/l	<3	<3	
Chloride (Cl)‡				
surface irrigation	me/l	<4	4–10	>10
sprinkler irrigation	me/l	<3	>3	
Boron (B)	mg/l	<0.7	0.7–3.0	>3.0
Trace elements (see Table 4.3)				
Miscellaneous effects (affects susceptible crops)				
Nitrogen ($NO_3 - N$)§	mg/l	>5	5–30	>30
Bicarbonate (HCO_3) (overhead sprinkling only)	me/l	<1.5	1.5–8.5	>8.5
pH		Normal range 6.5–8.4		

Source: Adapted from FAO (1985)

* EC_w means electrical conductivity, a measure of the water salinity, reported in deciSiemens per metre at 25°C (dSm) or in units millimhos per centimetre (mmho/cm). Both are equivalent. TDS means total dissolved solids, reported in milligrams per litre (mg/l).

† SAR means sodium adsorption ratio, and is sometimes reported by the symbol RNa. At a given SAR, infiltration rate increases as water salinity increases. Evaluate the potential infiltration problem by SAR as modified by EC_w

‡ For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride; use the values shown. Most annual crops are not sensitive. With overhead sprinkler irrigation and low humidity (<30%), sodium and chloride may be absorbed through the leaves of sensitive crops.

§ NO_3-N, nitrate nitrogen, reported in terms of elemental nitrogen (NH_4-N and organic−N should be included when wastewater is being tested).

Table 4.3 Recommended maximum concentrations of trace elements in irrigation water

Element	*Recommended maximum concentration* (mg/l)	*Remarks*
Al (aluminium)	5.0	Can cause non-productivity in acid soils (pH <5.5), but more alkaline soils at pH <7.0 will precipitate the ion and eliminate any toxicity
As (arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice
Be (beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans
Cd (cadmium)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions; conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans
Co (cobalt)	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution, tends to be inactivated by neutral and alkaline soils
Cr (chromium)	0.10	Not generally recognized as an essential growth element; conservative limits recommended due to lack of knowledge on its toxicity to plants
Cu (copper)	0.20	Toxic to a number of plants at 0.1–1.0 mg/l in nutrient solutions
F (fluoride)	1.0	Inactivated by neutral and alkaline soils
Fe (iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum; overhead sprinkling may result in unsightly deposits on plants, equipment and buildings
Li (lithium)	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil; toxic to citrus at low concentrations (<0.075 mg/l); acts similarly to boron
Mn (manganese)	0.20	Toxic to a number of crops at a few tenths to a few mg/l, but usually only in acid soils
Mo (molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water; can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum
Ni (nickel)	0.20	Toxic to a number of plants at 0.5–1.0 mg/l; reduced toxicity at neutral or alkaline pH
Pb (lead)	5.0	Can inhibit plant cell growth at very high concentrations
Se (selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium; an essential element to animals but in very low concentrations
Sn (tin) Ti (titanium) W (tungsten)		Effectively excluded by plants; specific tolerance unknown
V (vanadium)	0.10	Toxic to many plants at relatively low concentrations
Zn (zinc)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH >6.0 and in fine textured or organic soils

Source: Adapted from FAO (1985)

Table 4.4 Suggested treatment processes to meet the given health criteria for wastewater reuse

	Irrigation			Recreation		Industrial reuse	Municipal reuse	
	Crops not for direct human consumption	*Crops eaten cooked; fish culture*	*Crops eaten raw*	*No contact*	*Contact*		*Non-potable*	*Potable*
Health criteria (see below for explanation of symbols)	A + F	B + F or D + F	D + F	B	D + G	C or D	C	E
Primary treatment	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●
Secondary treatment		●●●	●●●	●●●	●●●	●●●	●●●	●●●
Sand filtration or equivalent polishing methods		●	●		●●●	●	●●●	●●
Nitrification						●		●●●
Denitrification								●●
Chemical clarification						●		●●
Carbon adsorption								●●
Ion exchange or other means of removing ions						●		●●
Disinfection		●	●●●	●	●●●	●	●●●	●●●*

Health criteria:

A Freedom from gross solids; significant removal of parasite eggs.
B As A, plus a significant removal of bacteria.
C As A, plus more effective removal of bacteria, plus some removal of viruses.
D Not more than 100 coliform organisms 100 ml in 80% of samples.
E No faecal coliform organisms in 100 ml, plus no virus particles in 1000 ml, plus no toxic effects on man, and other drinking-water criteria.
F No chemicals that lead to undesirable residues in crops or fish
G No chemicals that lead to irritation of mucous membranes and skin.

In order to meet the given health criteria, processes marked ●●● will be essential. In addition, one or more processes marked ●● will also be essential, and further processes marked ● may sometimes be required.

* Free chlorine after 1 h.

Source: WHO (1973)

evaluate the wastewater for irrigation purposes in terms of biochemical characteristics and Table 4.4 suggests treatment processes to reduce the risk to public health which is related to microbial characteristics of wastewater.

Other alternatives for crop selection if water quality is low and a hazard to public health can include forest crops which have the fewest associated risks to public health, industrial crops not to be consumed by humans or animals(such as cotton), or forage crops which are processed (dried) and stored (such as hay or pellets) before being fed to livestock.

At the end of his paper, Kandiah presents some standards developed by specific countries for the use of effluents. These existing standards can be an aid in establishing an appropriate program for the re-use of wastewater in terms of crops, treatment required, type of irrigation system and crop management. With experience and observation and research of field trials, all existing guidelines can be modified to fit a specific location.

استفاده مجدد از پساب در امر آبیاری

گروه تحقیق کمیته آب و فاضلاب

همه ما در این نکته که منابع آب گوارا محدود هستند هم عقیده‌ایم . علت آنکه انسان، طی سالیان قبل برای آبیاری مزارع مستقیما " از فاضلاب استفاده مینموده نیز همین امر بوده است . مصرف میوه‌جات خام وسبزیجات بدست آمده از این مزارع بعلت وجود ارگانیزمهای بیماریزا (پاتوژن ها) در آنها همواره سلامت انسان را به مخاطره می افکنده است . این ارگانیزمها شامل کرمهای انگلی ، پروتوزآ ، باکتریها و ویروسها میباشند .

درقرن معاصر به محتویات فاضلاب فلزات سنگین ومواد آلی سمی نیز افزوده شد . با گذشت زمان ضرورت تصفیه فاضلابهای مورد مصرف درآبیاری محسوس گردید .

درسال ۱۹۸۸ کتابی باعنوان " تصفیه فاضلاب واستفاده ازپساب آن درآبیاری " بوسیله م.ب پسکود و آ.آرار تالیف وتوسط F.A.O منتشر گردید.

مطالب این کتاب شامل بحثهای مطروحه در سمینار منطقه‌ای F.A.O درباره " تصفیه فاضلاب واستفاده ازپساب آن درآبیاری " که در نیکوزیا (قبرس) از هفتم تا نهم اکتبر ۱۹۸۵ برگزار گردید میباشد .

برطبق پیشنهادات مطرح شده دراین کتاب یک تیم ورزیده میتوانند راهنمائیهای لازم را در زمینه استفاده مجدد از فاضلاب با توجه به شرائط محلی خاص ارائه نماید .

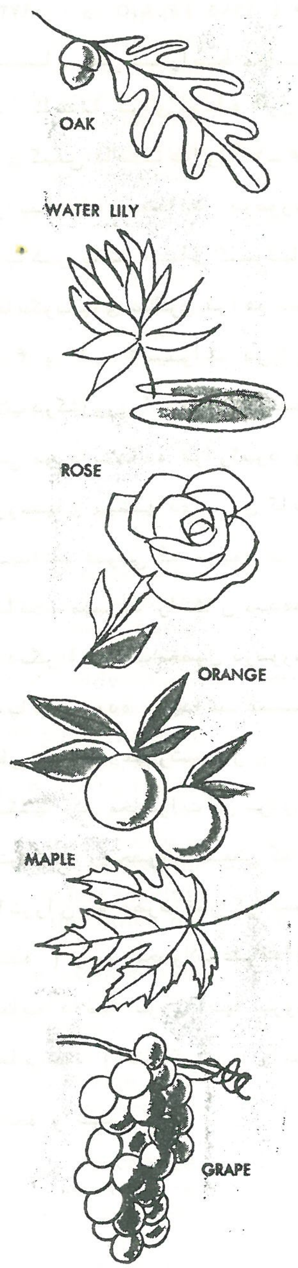
دربخش ۴ ، آ . کاندیا از بخش توسعه و زمین F.A.O در رم درمقاله خود تحت عنوان " معیارهای کیفی دراستفاده ازپساب فاضلاب برای تولید محصولات کشاورزی " مسائلی را طرح می نماید که هنگام استفاده مجدداز فاضلاب درکشاورزی بایستی مدنظر قرارگیرد . مراجع اصلی برای این معیارها گزارش ۱۹۷۳ سازمان بهداشت جهانی درباره استفاده مجدد ازفاضلاب و گزارش ۱۹۸۵ F.A.O درباره–

کیفیت آب درکشاورزی بود .

مقاله کاندیا نظری اجمالی براستفاده مجدد ازفاضلاب ، که عبارتست ازآب مصرف شده یک جامعه؛حاوی فضولات مردم، ساختمانهای تجاری وواحدهای صنعتی و آبهای سطحی و زیر ـ زمینی که وارد شبکه فاضلاب شهرمیشود میباشد (WHO ، ۱۹۷۳)،موارد دیگری نیز مورد بحث قرارگرفته است ، ازجمله امکان استفاده مجدد از فاضلابهای شهری درامر کشاورزی درمقیاسهای وسیع و بررسی اینکه آیا بازیابی فاضلاب درامور خاص بیشترمقرون بصرفه است یا تامین آب ازمنابع دیگر .

این مشگل درکشورهای درحال توسعه بیشتر نمایان است چرا که نوعا " غلظت آلاینده‌ها در فاضلابهای شهری بیشتر است وهزینه تصفیه مواد مضر کشاورزی درآن بالا است .

درصورتیکه فاضلاب تصفیه شده رادرآبیاری بکار ببرند دردرجه اول بایستی وضعیت میکروبی و بیوشیمیائی آن روشن شود . با روشن شدن مقدار این پارامترها میتوان مضرات بهداشت عمومی ، مخاطرات محیطی و ملاحظات کشاورزی (خصوصا " میزان شوری فاضلاب) رامورد ارزیابی قرارداد . گرچه واقعیت این است که کیفیت آب مورد مصرف درکشاورزی پائین تراز مصارف بهداشتی (آشامیدنی ، شستشو و ...) وصنعتی میباشد ولی بعلت تاثیراتی که میتواندبرروی خاک، گیاه ، محصول ومحیط مزرعه باقی بگذارد ، معیارهای کیفی بایستی مراعات گردند .



پساب فاضلاب باعث رشدسریعتر گیاهان میگردد.

معیارهای مطرح شده ازطرف سازمان بهداشت جهانی (۱۹۷۳) و F.A.O (۱۹۸۵) میتواند با ارزیابی شرایط محلی تلفیق شود. کاندیا برای مرحله اول ارزیابی محدودیتهای کیفی فاضلاب جداول* ۲ـ۴ و ۳ـ۴ و ۴ـ۴ راپیشنهاد مینماید. درصورتیکه کیفیت آب پائین باشد اعمال کنترلهای مناسب میتواند جایگزینهای دیگری فراهم نماید.

جداول ۲ـ۴ و ۳ـ۴ میتواند در ارزیابی مصرف فاضلاب درکشاوری ازنقطه نظرخصوصیات بیوشیمیائی موردا ستفاده قرارگیرد و جدول ۴ـ۴ پروسسهای پیشنهادی برای کاهش مخاطرات بهداشت عمومی که مربوط به خصوصیات میکروبی فاضلاب میباشد رانشان میدهد.

گزینه‌های دیگر انتخاب محصول درصورتیکه کیفیت آب پائین بوده وبهداشت عموم را درمعرض خطر بیفکند عبارتست از :

آبیاری جنگلها که مخاطرات آن برای سلامت همگان کمتر است ، محصولات صنعتی که توسط انسان وجانوران به مصرف خوراکی نمیرسد (نظیر پنبه) و یا محصولات علوفه‌ای که قبل از تغذیه دامها بروی آنها پروسس های مختلف انجام شده (خشک کردن) وانبار میگردد (نظیر یونجه و شبدر) .

کاندیا درپایان مقاله خود پاره‌ای از استانداردهای مصرف پساب را برای برخی ازکشورها ذکر میکند .

استانداردهای موجود میتواند درتثبیت برنامه مناسب استفاده مجدد ازفاضلاب درتولید محصولات کشاورزی ، تصفیه مورد نیاز ، نوع سیستم آبیاری وکنترل محصول موثر واقع شود.

با تجربه و تدبر و تحقیق در مورد شرائط عینی ، تمام خطوط راهنمائی موجودرا میتوان با شرائط محلی خاص منطبق نمود .

---

* : جداول درمقاله انگلیسی آخرنشریه آمده است .